PD 03W088

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	:	
Robert W. Byren *et al.*	:	Group Art Unit 2874
Serial No. 10/786,342	:	Examiner: Ullah, Akm E.
Filed: 02/24/2004	:	
For: STIMULATED BRILLOUIN...	:	

AFFIDAVIT UNDER 37 C.F.R. 1.131

Commissioner of Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

We hereby declare that we are the inventors STIMULATED BRILLOUIN SCATTERING PHASE CONJUGATE MIRROR UTILIZING PHOTONIC BANDGAP GUIDE AND METHOD disclosed and claimed in the above-identified patent application.

Enclosed herewith is a copy of an invention disclosure, which shows that the invention was conceived by us before November 19, 2003. We worked diligently on the invention from conception until the application was filed February 25, 2004. The conception and work on the invention occurred in the United States of America.

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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10/4/05

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David A. Rockwell Date

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10/7/05

Alexander A. Betin Date

Complete the information in the spaces provided. Use the TAB key to advance to the next field. Shift-TAB will move the cursor back one field. Either X or Space-bar can be used to check boxes where required.

Prepare the Invention Disclosure Form, except for the information on page 3. The original should be signed and witnessed where indicated. Send the original and three copies directly to the Regional Patent Engineer (see below). Have a copy reviewed and annotated by your department manager (through your immediate supervisor), and then by the manager of the program office or business area most likely to benefit from protection (via patent or trade secret) of your invention. Once you receive the appropriate comments and signatures, the executed copy and six additional copies should also be sent to the Regional Patent Engineer at (see attached instructions):

Inventors at ELCAN, ROSI, and sites in CA or AZ: Intellectual Property & Licensing Dept., Raytheon Company, 2000 East El Segundo Blvd (EO/E01/E150), El Segundo, CA 90245; Texas area: Intellectual Property & Licensing Dept., Raytheon Company, 13510 N. Central Expressway, M/S 200, Dallas, TX 75243; Northeast Region: Intellectual Property & Licensing Dept., Raytheon Company, 141 Spring Street, Lexington, MA 02421.

1. TITLE OF INVENTION

Stimulated Brillouin Scattering Phase Conjugate Mirror Utilizing Photonic Bandgap Guide and Method

2. INVENTOR(S) (If more than 3, identify additional inventors in Section 14 and check this box ☐)

(A) NAME (first, middle, last)	EMPLOYEE ID	PHONE	FAX NO.	COMPANY & SEGMENT	DEPT NUMBER
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(C) NAME (first, middle, last)	EMPLOYEE ID	PHONE	FAX NO.	COMPANY & SEGMENT	DEPT NUMBER
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Patent Department will determine legal inventorship

3. PROOF OF CONCEPTION

A. BY WHOM WAS FIRST DESCRIPTION WRITTEN OR DRAWING MADE?	DATE CONCEIVED	ACCT. CHARGED (TIME/MATERIAL)	LOCATION OF FIRST DESCRIPTION / DRAWING (TECHNICAL NOTEBOOK NO. AND PAGES)
Robin W. Byren	3/14/03	W3E3C1	This Disclosure

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	DATE RECEIVED	PATENT DOCKET NUMBER
Stimulated Brillouin Scattering Phase Conjugate Mirror Utilizing Photonic Bandgap Guide and Method		03W088

B. TO WHOM WAS INVENTION FIRST DISCLOSED?	DATE DISCLOSED	MANNER OF DISCLOSURE
Alexander A. Betin	1/6/03	Robert Byren described concept of using a PBG hollow guide with a gaseous SBS medium to provide high numerical aperture and low loss propagation for a phase conjugate mirror application at the PQE conference in Snowbird, UT.

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4. REDUCTION TO PRACTICE

A. WAS A DEVICE EMBODYING THE INVENTION CONSTRUCTED AND TESTED OR THE PROCESS PRACTICED?	YES ☐ NO ☒	BY WHOM	DATE STARTED	DATE COMPLETED	ACCT. CHARGED (TIME/MATERIAL)
B. PRESENT LOCATION OF DEVICE AND ALL DOCUMENTS SHOWING REDUCTION TO PRACTICE					

5. RELATIONSHIP TO GOVERNMENT CONTRACT

A. WAS THIS INVENTION CONCEIVED AND/OR REDUCED TO PRACTICE UNDER GOVERNMENT CONTRACT?	YES ☐ NO ☒	CONTRACT NUMBER AND TITLE
B. TO ASSIST RAYTHEON IN COMPLYING WITH GOVERNMENT REPORTING REQUIREMENTS, PLEASE PROVIDE CONTACT IN GOVERNMENT AGENCY AND RAYTHEON CONTRACTS DEPARTMENT (IF KNOWN).		

6. RELATIONSHIP TO COMPANY-FUNDED PROGRAM

A. WAS THIS INVENTION CONCEIVED AND/OR REDUCED TO PRACTICE AS PART OF A COMPANY-FUNDED PROGRAM/PROJECT?	YES ☐ NO ☒	IDENTIFY PROJECT TITLE, NUMBER, ETC.

7. RELATED DOCUMENTS

A. ARE THERE ANY RELATED INVENTION DISCLOSURES OR PATENT APPLICATIONS?	YES ☐ NO ☒	IDENTIFY FILE OR CASE NUMBER, ETC.
B. ARE THERE ANY RELATED ISSUED PATENTS OR TECHNICAL PUBLICATIONS?	YES ☐ NO ☒	IDENTIFY

8. USE, COMMERCIALIZATION AND FOREIGN MARKETS

A. ARE YOU AWARE OF ANY POTENTIAL COMMERCIAL APPLICATIONS FOR THE INVENTION?	YES ☒ NO ☐	IDENTIFY POTENTIAL CUSTOMER, APPLICATION, TIME FRAME This invention is applicable to a broad range of applications requiring high power, pulsed solid-state lasers with good beam quality. Specific applications include remote sensing (e.g., space-based wind profiling and pollution monitoring), and scientific.
B. ARE YOU AWARE OF ANY FOREIGN MARKETS FOR THIS INVENTION?	YES ☒ NO ☐	IDENTIFY COUNTRIES, APPLICATIONS, TIME FRAME Foreign military markets include Germany, United Kingdom, France, and Israel.
C. HAS THE INVENTION BEEN OR IS THE INVENTION TO BE INCORPORATED INTO A COMPANY PRODUCT OR PROGRAM?	YES ☒ NO ☐	PRODUCT(S) OR PROGRAM(S), TIME FRAME This is one of several PCM approaches that were considered for the Strategic Illuminator Laser (SILL) proposal. Other applications include ABL, SBL, High Altitude Aerostat, MKV, and others.

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9. DEPARTMENT MANAGER COMMENTS TO PATENT EVALUATION COMMITTEE

This invention is directly applicable to a broad range of high power laser illuminator applications where short pulse lengths and high beam quality are required, examples include illuminator lasers for active tracking and wavefront sensing as well as incoherent LADAR sources for remote sensing. This invention takes advantage of recent breakthroughs in photonic bandgap light guiding structures in a fiber geometry. It improves conjugator performance by providing a high numerical aperture with low propagation loss. It solves a specific problem with gaseous SBS lightguides, which cannot use total internal reflection at a refractive index discontinuity to guide the beam.

NAME C. Thomas Hastings, Jr.	SIGNATURE	DATE	PHONE 647-0804

10. PROGRAM OR BUSINESS OFFICE COMMENTS TO PATENT EVALUATION COMMITTEE

This inventive phase conjugate mirror configuration provides a high payoff alternative to conventional liquid lightguide SBS PCM devices for high power, pulsed laser illuminators. The NASA Langley 2 micrometer source, ABL TILL follow-on and related programs will benefit immediately from this technology. Long-range remote sensing and civil space markets will also benefit from this technology. The addressable market for this technology (illuminators only) is in the tens of millions per year.

NAME Chauncey McKearn	SIGNATURE	DATE	PHONE 647-4489

11. SUPERVISOR: please affirm the charge number and program data provided in sections 3, 4, 5, and 6 of this disclosure.

SUPERVISOR NAME	SIGNATURE	DATE	PHONE
C. Thomas Hastings, Jr.			647-0804

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Stimulated Brillouin Scattering Phase Conjugate Mirror Utilizing Photonic Bandgap Guide and Method	DATE RECEIVED	PATENT DOCKET NUMBER

TITLE OF INVENTION

Stimulated Brillouin Scattering Phase Conjugate Mirror Utilizing Photonic Bandgap Guide and Method

INVENTOR(S) (Additional Inventors may be listed in Section 14)

Robert W. Byren	David A. Rockwell	Alexander A. Betin

12. PUBLICATION, SALE, OR PUBLIC USE

A. HAS THE INVENTION BEEN DISCLOSED TO A THIRD PARTY WITHOUT THE EXECUTION OF A NON-DISCLOSURE, PROPRIETARY, OR OTHER CONFIDENTIALITY AGREEMENT?	YES ☐ NO ☒	DATE	TO WHOM
B. HAS THE INVENTION BEEN USED, DISCUSSED, DEMONSTRATED OR OTHERWISE DISCLOSED OUTSIDE THE COMPANY (SUCH AS TO A VENDOR OR CUSTOMER)?	YES ☒ NO ☐	DATE	TO/FOR WHOM (COMPANY/PERSON) This invention was discussed in detail with HRL Laboratories, LLC personnel and a directed research project was recently established with HRL to advance the technology and demonstrate performance in a solid fiber configuration.
C. HAS THE INVENTION BEEN SOLD OR OFFERED FOR SALE?	YES ☐ NO ☒	DATE	TO WHOM
D. IS THERE A PUBLICATION OR PUBLIC PRESENTATION RELATED TO THE INVENTION? (This includes the Internet)	YES ☐ NO ☒	DATE	IDENTIFY
E. HAS A MANUSCRIPT DESCRIBING THE INVENTION BEEN SUBMITTED FOR PUBLICATION?	YES ☐ NO ☒	DATE	TO WHOM
F. IF THE ANSWER TO E. WAS YES, HAS THE MANUSCRIPT BEEN ACCEPTED FOR PUBLICATION?	YES ☐ NO ☐	DATE	WHEN AND WHERE WILL IT BE PUBLISHED?

INVENTOR(S) SIGN AND DATE:

WITNESS NAME (PRINT)	WITNESS SIGNATURE	DATE	WITNESS NAME (PRINT)	WITNESS SIGNATURE	DATE

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Stimulated Brillouin Scattering Phase Conjugate Mirror Utilizing Photonic Bandgap Guide and Method		

13. SUMMARY OF THE INVENTION

A. STATEMENT OF THE PROBLEM SOLVED BY THE INVENTION

Traditional phase conjugate mirrors based on the nonlinear stimulated Brillouin scattering process (SBS) use bulk focusing within the nonlinear SBS medium to achieve the high electric field intensity necessary to generate the Stokes field. The bulk focus approach, however, limits the performance of the conjugator in two ways. First, the threshold for SBS phase conjugation is related to the field intensity as well as the interaction length. By reducing the focal length to increase the field intensity, the focal distance is also reduced thereby limiting the interaction length for the nonlinear process. This results in a high peak power threshold for phase conjugation that makes bulk focus SBS impractical for some high average power, high pulse rate applications. Second, the short interaction length does not allow good diffractive mixing between different parts of the beam which adversely affects phase conjugation fidelity, especially for highly aberrated beams with deep intensity modulations.

B. PRIOR ATTEMPTS OF OTHERS TO SOLVE THIS PROBLEM

It is well known in the art that the performance of SBS phase conjugate mirrors benefit from the long gain-length and the good diffractive mixing that occurs in a guided geometry. Metal guides have been demonstrated with both gasseous and liquid SBS media for this purpose, but are typically very lossy. Hollow capillary glass lightguides have been demonstrated with higher-index liquid SBS media such that the beam propagates down the guide with very low loss via total internal reflection at the liquid-to-glass interface. The numerical aperture of the guide is limited by the difference in refractive indices of the liquid and glass. This limiting numerical aperture sets a limit on the etendue (divergence-aperture product) of the input beam for good phase conjugation. Also, uncoated glass lightguides cannot be used with gaseous media, as the index of refraction of the glass is greater than that of the gas media preventing total internal reflection. Conventional glass-core fibers have been used for SBS phase conjugation, but these suffer from the same numerical aperture limits as the liquid guides. Depolarization of the beam within the guide degrades the performance of the PCM. Lengthening a conventional guide in order to enhance the nonlinear interaction or bending it to minimize space tend to exacerbate the depolarization problem.

C. HOW YOUR INVENTION SOLVED THIS PROBLEM

This invention uses a new type of lightguide based on a photonic bandgap structure to create a guided SBS phase conjugate mirror. The photonic bandgap structure can be made with a high numerical aperture allowing operation with highly distorted input beams. It can be made with a solid core, in which SBS occurs in the solid core region. It can also be made with a hollow core, allowing use with both gas and liquid SBS media. Because the reflection results from Bragg diffraction and not total internal reflection, there is no problem in using the photonic bandgap hollow-core "fiber" with gas SBS media.

D. WHY YOU BELIEVE THAT THE INVENTION IS NEW (Specifically point out all novel features)

This is believed to be the first application of a photonic bandgap guiding structure in a self-pumped stimulated Brillouin scattering (SBS) phase conjugate mirror (PCM).

A keysearch of the USPTO Patent Full Text and Image Database using the following Boolean logic: abst/(photonic AND (bandgap OR crystal)). This search yielded 65 hits, 13 of which were reviewed in detail and none were directly related to the present invention.

A keyword patent search was performed using the following Boolean logic: abst/(phase AND (conjugate OR conjugation) AND (Photonic OR bandgap OR PBG)). This search yielded only 1 hit, which was not remotely related to the present invention.

Several publications were found, which suggested the enhancement of nonlinear process (including SBS) by using photonic bandgap guiding structures. Most addressed the use of hollow core fibers to increase the threshold for SBS, allowing higher powers to be transmitted through an optical fiber over long distances for telecommunications applications (this is actually counter to the applications invisioned in the present invention).

14. DETAILED DESCRIPTION.

Use the Invention Disclosure Continuation Sheet to provide a detailed written description of your invention, using as many pages as necessary. Be certain to include a description of the "best mode" or best means of practicing the invention known to you at this time. You may insert figures, tables, and photos into this section, or you can attach copies of relevant proposals, prior art, or other documentation that will assist the Patent Evaluation Committee in fully considering your invention. (Note: Please place information on additional inventors first in this section).

INVENTOR(S) SIGN AND DATE:

WITNESS NAME (PRINT)	WITNESS SIGNATURE	DATE	WITNESS NAME (PRINT)	WITNESS SIGNATURE	DATE

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Background of Invention:

SBS Phase Conjugation

Stimulated Brillouin Scattering (SBS) is a commonly used nonlinear (electric field intensity dependent) process for generating the phase conjugate of a narrow-band input optical beam with no external pumps (i.e., self-pumped nonlinear optical phase conjugation). The SBS process is well known in the art and is described in several open literature references, including R. A. Fisher's book entitled *Optical Phase Conjugation* (Academic Press, New York, 1983). For input optical beams having high peak power (> 100 kW) and moderately good beam quality (< 20 times diffraction limited), SBS can be used with simple bulk focusing to provide high phase conjugate mirror (PCM) reflectivity and good phase conjugation fidelity. A typical bulk focusing SBS geometry is shown schematically in Figure 1.

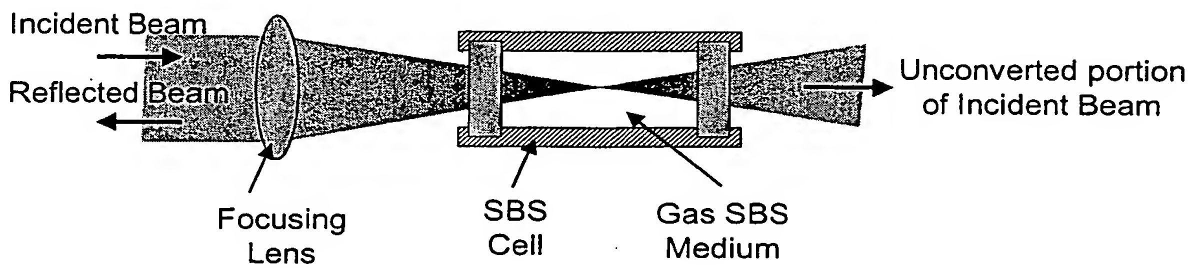

Figure 1. SBS Phase Conjugate Mirror using Gaseous Medium in Bulk Focus Geometry

PCM reflectivity in this context is the ratio of reflected to incident beam powers. The maximum achievable value of PCM reflectivity is nearly 100%, limited by the percentage of incident power that is converted to acoustic power in the medium (Manley-Rowe limit). Phase conjugation fidelity measures the ability of a PCM to return a beam that is an exact conjugate of the input beam. A rigorous definition of phase conjugation fidelity (χ) is given by the following:

$$\chi = \frac{\left| \int E_{OUT} \cdot E_{IN}\, dx\, dy \right|^2}{P_{OUT} \cdot P_{IN}}$$

where: E_{IN} and E_{OUT} are the incident and reflected electric field amplitude profiles
P_{IN} and P_{OUT} are the incident and reflected powers

The fidelity is the fraction of the reflected power contained in an eigenmode that is conjugate to the incident field. The maximum achievable value of phase conjugation fidelity is 100%.

For low peak power or highly aberrated incident beams, the bulk focus geometry may provide low reflectivity and/or poor phase conjugation fidelity. The low reflectivity results from the fact that the SBS gain is exponentially dependent on the product of the nonlinear gain of the medium, incident intensity, and interaction length in the focal volume. If the focal length of the focusing lens

is shortened to decrease the focal spot size in order to increase the incident beam intensity, the focal volume is foreshortened thereby reducing the interaction length. Increasing the focal length has the converse effect. The result is that the SBS gain for a given medium cannot be arbitrarily improved in a focusing geometry by simple parametric adjustments. The minimum SBS phase conjugate mirror power threshold in a focused geometry corresponds to a gaussian beam with a typical value in the 1 μm wavelength region that exceeds tens of kilowatts. For highly aberrated beams with complex wavefronts, the SBS PCM threshold increases proportionally to the beam divergence (étendue) and can be above hundreds of kilowatts, which is too high for laser applications with long pulse or CW optical waveforms.

HRL Laboratories and others have shown that PCM reflectivity/threshold and phase conjugation fidelity can be improved for low power and/or highly aberrated beams by incorporating the SBS medium in a lightguide geometry. See, for example:

1. D.C. Jones, M.S. Mangir, and D.A. Rockwell, "A Stimulated Brillouin Scattering Phase-conjugate Mirror Having a Peak-Power Threshold <100 W," *Optical Communications* 23, pp. 175–181, 1995.
2. M.S. Mangir, "Measurements of SBS Reflectivity and Phase Conjugation Fidelity in Light Guides," *Nonlinear Optics: Materials, Fundamentals, and Applications Conference,* Kauai, Hawaii, July 1998.

One embodiment of the lightguide geometry is shown in Figure 2. The SBS medium is a liquid, such as CS_2 or $TiCl_4$, both of which have a high SBS nonlinear gain. The lightguide is formed by a small internal diameter (< 0.5 mm) glass capillary, which is immersed in the liquid SBS medium. The index of refraction of the capillary is less than that of the liquid allowing reflection off the inner walls of the capillary via total internal reflection for shallow grazing angles.

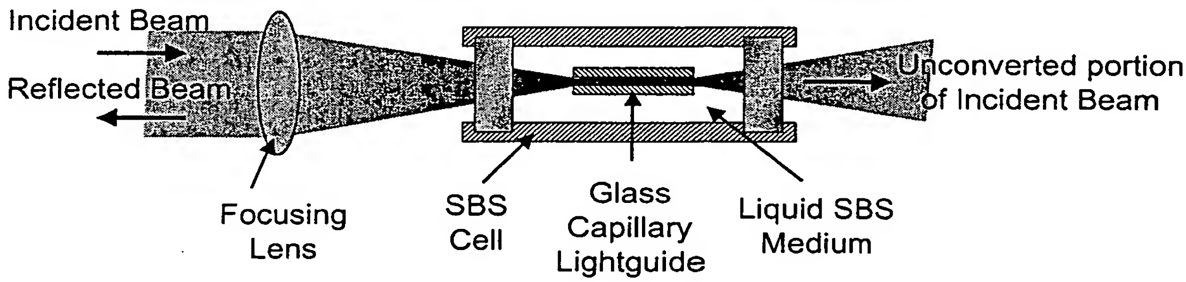

Figure 2. SBS Phase Conjugate Mirror using Liquid Medium in Lightguide Geometry

There are several limitations of the liquid lightguide SBS PCM described above. First, it is not practical with gas media, as the lower index of refraction of the gas medium will not allow total internal reflection. Metal guides have been used with gas media to circumvent this problem, but metal guides are lossy. Second, the SBS threshold increases with higher angles of incidence entering the guide, thereby causing the SBS reflectivity to fall off with incidence angle. A condition for good phase conjugation fidelity is that all portions of the beam have essentially the same reflectivity. This condition limits the acceptance angle of the guide for phase conjugation to a value well below that determined by geometrical optics (numerical aperture of the guide) restricting the étendue (divergence – aperture product) of the incident beam. Finally, phase conjugation is a scalar process, and depolarization of the incident beam within the lightguide represents a loss of phase information and attendant loss of phase conjugation fidelity. Depolarization is caused by phase shifts between the s and p waves reflected via total internal reflection within the guide. Depolarization increases with the length of the guide and is exacerbated by bending/coiling the guide to make the PCM more compact.

Photonic Bandgap Crystals and Fibers

The concept of a Bragg fiber was proposed in the late 1970's by Amnon Yariv and Pochi Yeh, The first microstructured or "holey" fiber was fabricated J.C. Knight, et al, at ORC, Southampton in 1996, and the first microstructured fiber which guided light by a photonic bandgap effect was fabricated by R. F. Cregan, et al, at the University of Bath. The "holey" fiber considered in the present invention is typically a silica fiber with a periodic array of small holes running parallel to the fiber axis, which strongly affect the optical properties of the fiber. The center or core of the fiber through which the beam is propagated is either solid silica or has a hole, often larger than the holes in the surrounding periodic array. Figure 3 shows the latter configuration. These microstructured fibers may be fabricated by stacking and fusing glass tubes together then drawing the preform structure into long fibers using conventional fiber manufacturing processes.

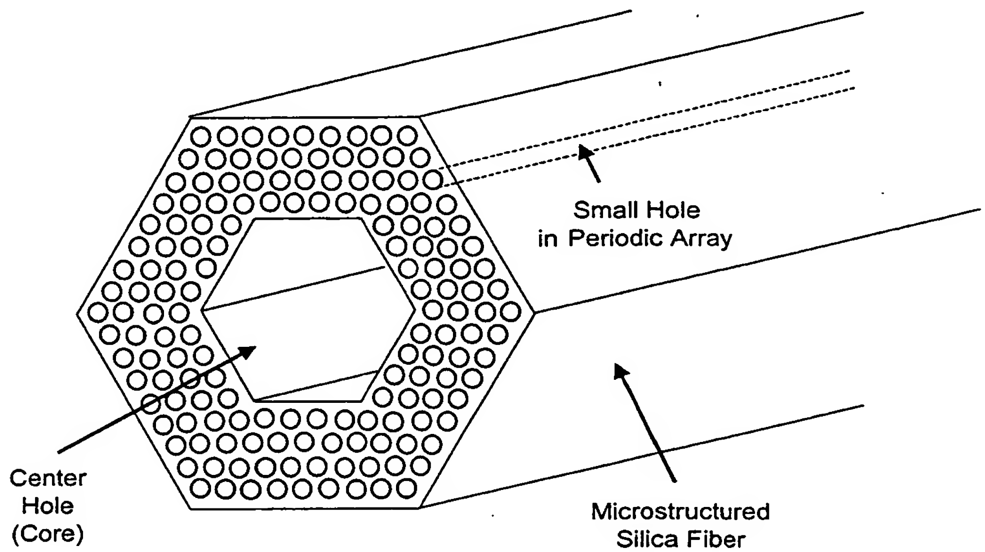

Figure 3. Photonic Bandgap Fiber with Hole in Center

The theory of photonic bandgap guidance in a holey fiber is well described by R. F. Cregan, et al in an article entitled "Single-Mode Photonic Band Gap Guidance of Light in Air," published in *Science*, Vol 285, pp. 1537–1539, 3 Sept 1999. Two guidance regimes are discussed with respect to PBG structures comprising alternating layers of high and low index as in the holey fiber structure shown in Figure 3: (1) frustrated tunnelling PBG guidance and (2) Bragg PBG guidance. In frustrated tunneling PBG guidance regime , the light propagates in the layers of high index (surrounding silica material) but is evanescent in the layers of low index (small holes). Light leakage across the holes between the high index regions through resonant tunneling determines which modes are guided (leakage through resonant tunneling within passband) and which are not (resonant tunneling frustrated within band gap). In the Bragg PBG guidance regime, light can propagate in all layers (not evanescent), however band gaps occur at the Bragg condition, resulting from multiple scattering and interference.

The PBG guidance process does not require a core region with higher index than the cladding, allowing efficient propagation in a gas core fiber. This offers several advantages for high power fiber transmission, including high thresholds for breakdown and deleterious nonlinear processes such as SBS and stimulated Raman scattering. Additionally, the properties of the PBG fiber such as dispersion can be readily engineered by tailoring the geometry of the structure (hole spacing and fill factor). Additional advantages

include extremely low coupling between propagating modes, even with tight bends in the fiber; single mode operation with large core sizes; and high polarization purity with just slight assymetry in the structure. The performance of the PBG fiber are affected by defects in the structure and the finite extent of the periodic array. Defects, for example, introduce localized discontinuities in the bandgap. The finite structure increases contributes to optical loss within the fiber.

Detailed Description of Present Invention:

The present invention builds on the advances in the field of photonic bandgap fibers. Rather than using the large core diameter afforded by the photonic bandgap structure to suppress nonlinear processes, we encourage the nonlinear stimulated Brillouin scattering process by using a suitably small fiber core diameter and by exploiting the high numerical aperture and polarization preserving properties of the PBG guide to enhance nonlinear optical phase conjugation performance. Although utilizing PBG fibers "for the generation of multiple optical wavelengths by nonlinear processes, and more generally in enhanced nonlinear optics" has been suggested in the open literature references [R.F. Cregan paper cited earlier], practical schemes for using PBG structures in guiding SBS PCM devices have not been disclosed.

Figure 4 illustrates one embodiment of the present invention wherein a gas core PBG fiber is filled with a gaseous SBS medium, which may include essentially pure CH_4, N_2, or Xe, mixtures thereof, or other gasses and gas mixtures. The high index cladding structure is composed of a homogeneous solid material that is transparent at the propagation wavelength, such as silica. The PBG cladding supports guided modes in the gas core through either frustrated tunneling PBG guidance or Bragg PBG guidance as described above. The PBG structure may be engineered with a degree of asymmetry through techniques known in the art to enhance the birefringence of the fiber and thus maintain the polarization state of the propagated beam. Such asymmetry may be introduced by fabricating the fiber with an elliptical core, and this can be accomplished by stacking capillaries with different wall thickness in the preform, as described by J. Knight, et al in an article entitled "Photonic Crystal Fibers" published in Optics and Photonics News, pp. 26-30, March 2002. The PBG structure may be engineered to support a large number of propagation modes with near equal reflectivity, thereby allowing the PCM to operate with highly aberrated beams (high étendue) with good phase conjugation fidelity.

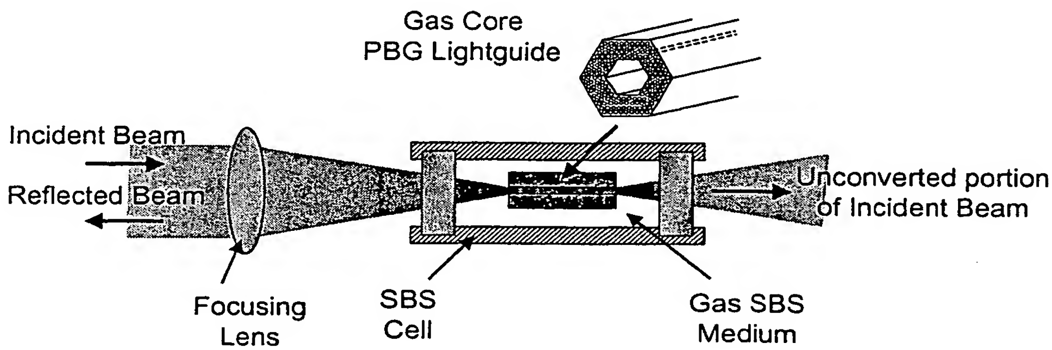

Figure 4. SBS PCM with Gas Core PBG Lightguide

The gas-core fiber structure shown in Figure 4 can also be used with liquid and gel SBS media. Liquid media may include CS_2 or $TiCl_4$. The small holes in the PBG structure may require sealing at the ends to preserve index homogeneity within these regions. DC 93500 silicone rubber, obtained from Dow Corning, may be used as the sealing material at the ends of the fiber.

Figure 5 illustrates an alternate embodiment of the present invention wherein the PBG fiber is fabricated with a solid core, which may be the same material as the high index cladding.

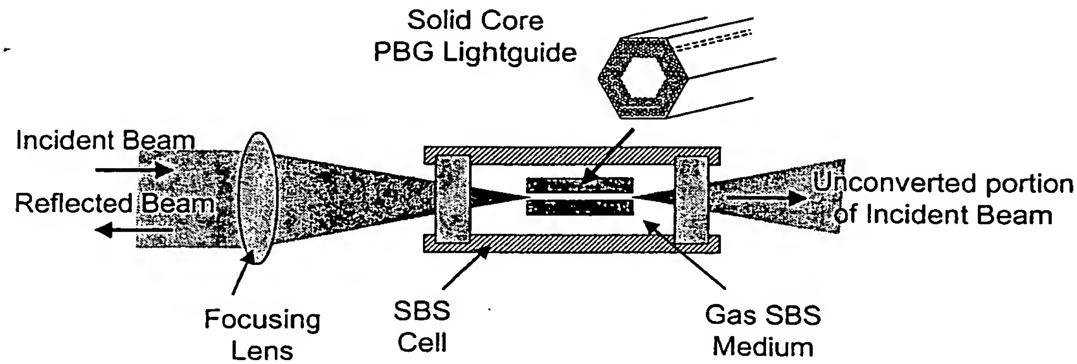

Figure 5. SBS PCM with Solid Core PBG Guide

There are several important applications where this invention is particularly advantageous. The first is in a phase conjugate master oscillator / power amplifier (PC MOPA) laser system such as that described by W. Koechner in his book *Solid-State Laser Engineering, Second Edition*, Springler-Verlag, Berlin, Germany, pp. 535-539, 1988. For PC MOPAs that operate in the high average power and high pulse rate regime, the PBG-guided SBS PCM may provide high PCM reflectivity with good phase conjugation fidelity for beams that are highly aberrated by the phase distortions in the power amplifier beamline. The second application is in an integrated phase conjugate laser and adaptive optics beam control system such as that described by R. Byren and A. Trafton in co-pending patent application number 20030062468, entitled "System and Method for Effecting High-Power Beam Control with Adaptive Optics in Low Power Beam Path." The third application is in a compensated imaging system such as that described by T. O'Meara in "Applications of Nonlinear Phase Conjugation in Compensated Active Imaging," in *Optical Engineering, Vol 21*, pp. 231-236 (1982). Other applications for the present invention may be envisioned by those skilled in the art without restricting the scope of the present invention.

It should be appreciated that the drawings and descriptions of the embodiments of the present invention described above are exemplary and that different hole patterns (e.g., rectangular symmetry), cladding thicknesses, focusing apparatus and geometries (multi-lens refractive systems, reflective systems, or diffractive systems), lightguide geometry (different core diameter to length aspect ratios, tapered geometries, etc.) do not depart from the scope and spirit of the invention. In addition, other nonlinear processes, such as stimulated Raman scattering, that may benefit from the reflectivity, dispersion, and étendue properties of the PBG guide described herein are also included within the scope of this invention.

INVENTOR(S) SIGN AND DATE:					
WITNESS NAME (PRINT) Robin A. Reeder	WITNESS SIGNATURE	DATE	WITNESS NAME (PRINT) Douglas A. Anderson	WITNESS SIGNATURE	DATE

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Title from disclosure form	DATE RECEIVED	PATENT DOCKET NUMBER
Slab Laser and Method with Improved and Directionally-homogenized Beam Quality		